

Chapter 5: IMPACT OF SULFUR TAX ON AIR QUALITY IN TWO HYPOTHETICAL AIR QUALITY CONTROL REGIONS

5.1 Introduction

This chapter briefly examines the effect of a sulfur tax on ambient sulfur dioxide (SO_2) concentrations in two hypothetical Air Quality Control Regions (AQCR's). A proportional model is used to relate annual sulfur emissions to annual arithmetic mean SO_2 concentrations. This model assumes uniform air quality across a region and a proportional relationship between changes in emissions and air quality. It is recognized that air quality varies across most regions; quality varies according to location and temporal and climatic conditions. The use of the proportional model here is only expositional; diffusion modeling is required to predict the distribution of air quality within a region. The effects of several sulfur tax rates on emissions and on SO_2 concentrations are compared, and the required tax rates to achieve the National Ambient Air Quality Standards for SO_2 in each region are determined.

5.2 Relationship between SO_2 Concentration and Sulfur Emissions

Assuming ambient pollutant concentration proportional to pollutant emissions, the concentration, C , resulting from a reduction in emissions is given by:

$$C = C_p (1 - r) \quad (1)$$

where C_p is the initial ambient pollutant concentration and r is the reduction in emissions expressed as a decimal percent.

Similarly, emissions after reduction, E , can be obtained from:

$$E = E_p (1 - r) \quad (2)$$

where E_p is initial emissions and r is defined above.

If an ambient air quality standard, C_s , is specified:

$$C_s = C_p (1 - r) , \quad (3)$$

then this equation, upon dividing both sides by C and changing signs, gives the familiar proportional equation:

$$\frac{C_p - C_s}{C_p} = r . \quad (4)$$

Thus, Eq. 1 can be used to calculate a new pollutant concentration resulting from a reduction in emissions, Eq. 2 can be used to calculate the emissions corresponding to a specified decimal percent reduction, and Eq. 4 can be used to calculate the required decimal percent reduction in emissions to achieve a specified ambient air quality standard.

5.3 Hypothetical AQCR's

5.3.1 Hypothetical AQCR A

This AQCR contains a petroleum refinery, a sulfuric acid plant, and point and area combustion sources of sulfur emissions including steam-electric power plants. Estimated annual uncontrolled sulfur emissions are 568,301 tons. Table 28 shows the distribution of emissions by source. The annual arithmetic mean SO_2 concentration is 0.085 ppm.

Table 28. Sulfur emissions by source for two hypothetical Air Quality Control Regions*
(tons per year)

Source	Uncontrolled	Tax Rate (cents per ton of sulfur emissions)					
		5	10	15	20	25	30
<u>AQCR A</u>							
Petroleum refineries	47,597	40,750	35,845	34,079	34,079	34,079	34,079
Sulfuric acid plants	11,294	11,294	3,298	1,357	1,295	1,094	1,094
Primary nonferrous smelters							
Lead	0	0	0	0	0	0	0
Zinc	0	0	0	0	0	0	0
Copper	0	0	0	0	0	0	0
Stationary combustion	509,410	182,157	105,975	79,227	61,817	61,553	56,847
Total	568,301	234,201	145,118	114,663	97,191	96,726	92,020
<u>AQCR B</u>							
Petroleum refineries	19,776	17,083	15,539	14,690	14,465	14,465	14,465
Sulfuric acid plants	13,265	13,265	2,345	1,670	1,435	1,435	1,368
Primary nonferrous smelters							
Lead	10,373	10,373	10,373	2,581	2,581	2,581	2,581
Zinc	781	781	79	79	79	79	79
Copper	0	0	0	0	0	0	0
Stationary combustion	450,393	148,203	85,948	68,532	66,236	45,072	42,463
Total	494,588	189,705	114,284	87,552	84,796	63,632	60,956

*These are representative of large metropolitan regions.

5.3.2 Hypothetical AQCR B

This AQCR contains a primary nonferrous smelter, a petroleum refinery, a sulfuric acid plant, and point and area combustion sources of sulfur emissions including steam-electric power plants. Estimated annual uncontrolled sulfur emissions are 494,588 tons. Table 28 shows the distribution of emissions by source. The annual arithmetic mean SO_2 concentration is 0.047 ppm.

5.4 Effect of Sulfur Tax on Emissions and Ambient SO_2 Concentrations

5.4.1 Sulfur Emissions

The relationship between annual sulfur emissions and tax rate for the two hypothetical AQCR's is shown in figure 31. Annual sulfur emissions and the decimal percent reduction in annual sulfur emissions associated with each tax rate, as well as the annual sulfur emission and decimal percent reduction required to achieve the National Ambient Air Quality Standards for SO_2 (0.03 ppm annual arithmetic mean), are shown in table 29.

5.4.2 Ambient SO_2 Concentrations

The reductions associated with each tax rate in table 29 and the initial SO_2 concentrations were substituted in Eq. 1 to calculate the

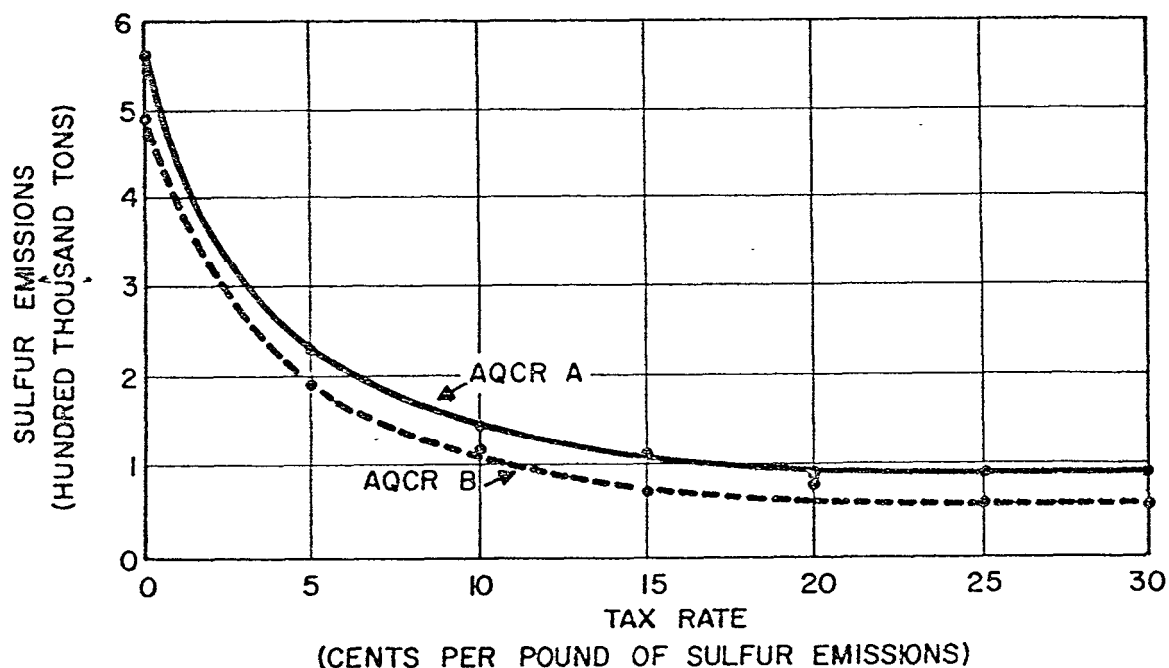


Figure 31. Effectiveness of a tax on sulfur emissions for two hypothetical Air Quality Control Regions (Source: Research Triangle Institute).

Table 29. Annual sulfur emissions and percent reduction with various tax rates

	Tax rate (cents per pound of sulfur emissions)							To achieve ambient air quality standard
	0	5	10	15	20	25	30	
Hypothetical AQCR A								
Annual sulfur emissions (tons/year)	568,301	234,201	145,118	114,663	97,191	96,726	92,020	198,905*
Reduction (decimal percent)	0	0.59†	0.75	0.80	0.83	0.83	0.84	0.65‡
Hypothetical AQCR B								
Annual sulfur emissions (tons/year)	494,588	189,705	114,284	87,552	84,796	63,632	60,956	316,536*
Reduction (decimal percent)	0	0.62†	0.77	0.82	0.83	0.87	0.88	0.36‡

*Calculated from Eq. 2.

†Calculated by rearranging Eq. 2 and solving for r.

‡Calculated from Eq. 4.

corresponding annual arithmetic mean SO_2 concentrations which are plotted in figure 32. Inspection of figure 32 indicates that the standard would be achieved at tax rates approximating 6 and 2 cents per pound of sulfur in AQCR's A and B, respectively.

The simplified analysis presented herein illustrates the relationship between sulfur emissions and ambient SO_2 concentrations and the effect of increasing sulfur tax rates on both. However, it must be remembered that the assumed proportionality describes air quality in terms of one concentration, which is assumed to prevail throughout the AQCR. Since the sulfur tax would permit each source to select a cost minimizing mix of tax payments and emission control expenditures, the air quality standard may be exceeded in the vicinity of some sources if the tax rate is too low. To adequately explore the regional effects of a sulfur tax, it would be necessary to employ a diffusion model capable of examining the influence of individual sources on air quality.

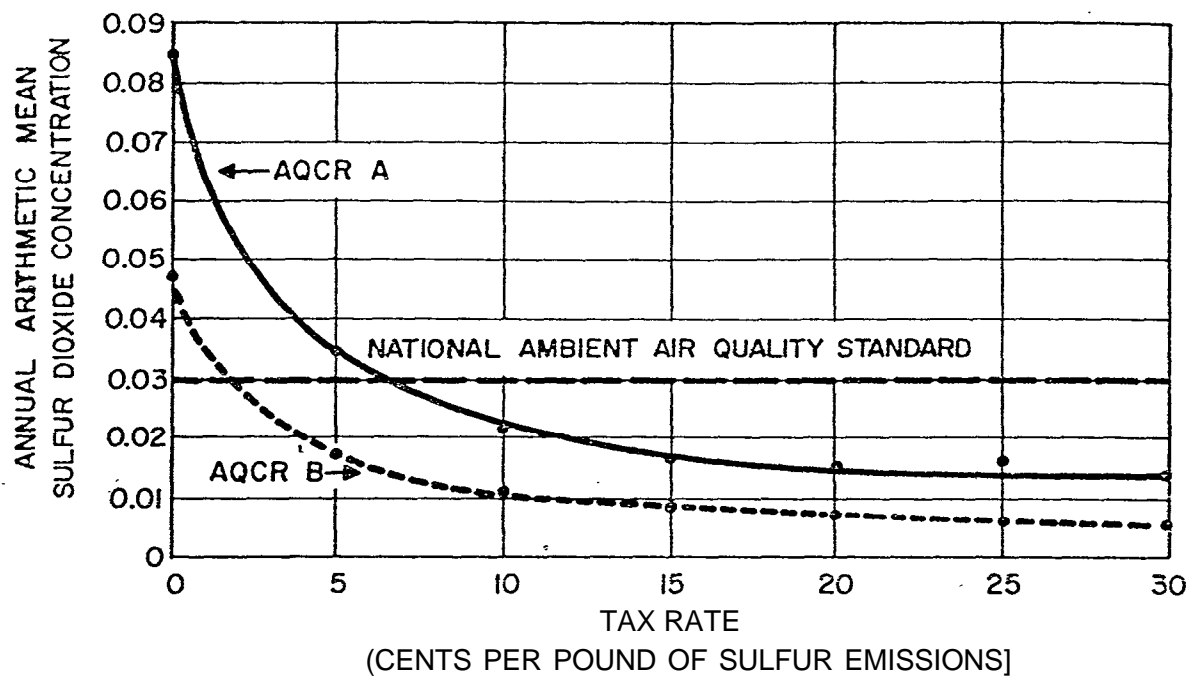


Figure 32. Relationship between tax rates and air quality for two hypothetical Air Quality Control Regions (Source: Research Triangle Institute).

BIBLIOGRAPHY

- American Petroleum Institute. Petroleum Facts and Figures. New York, 1971.
- Ayres, R. U., and Kneese, A. V. "Production, Consumption, and Externalities." American Economic Review 59, No. 3 (June 1969):282-297.
- Barrett, Larry B., and Waddell, Thomas E. Cost of Air Pollution Damage: A Status Report. Environmental Protection Agency, National Environmental Research Center, Research Triangle Park, N.C., 1973.
- Bassett, Lowell R., and Borcharding, T. E. "Externalities and Output Taxes." Southern Economic Journal 36 (April 1970):462-464.
- Battelle Memorial Institute, Pacific Northwest Laboratories. A Review and Comparison of Selected United States Energy Forecasts. Prepared for the Executive Office of the President, Office of Science and Technology, Energy Policy Staff, 1969.
- Baumol, W. J. "On Taxation and the Control of Externalities." The American Economic Review 62, No. 3 (June 1972):307-22.
- Bechtel Corporation. The Economics of Residual Fuel Oil Desulfurization. Prepared for U.S. Department of Health, Education, and Welfare, Public Health Service, June 1964.
- Bradshaw, Thomas T. "Closing Circle on Environmental Economics." Chemical and Engineering News, February 21, 1972, pp. 22-33.
- Buchanan, J. M., and Stubblebine, W. C. "Externality." Economica, November 1962, pp. 371-84.
- Buckingham, Paul, and Homan, Harry R. "Sulfur and the Energy Industry." Hydrocarbon Processing 67, No. 8 (August 1971):121-125, Fluor Corporation, Los Angeles, Calif.
- Burchard, John K.; Rochele, Gary T.; Schofield, William R.; and Smith, John O. Some General Economic Considerations of Flue Gas Scrubbing for Utilities. Environmental Protection Agency, Research Triangle Park, N.C., 1972.
- Chapman, Duan; Mount, Timothy; and Tyrrell, Timothy. Predicting the Past and Future in Electricity Demand. Department of Agricultural Economics, Cornell University, Ithaca, N.Y., 1972.
- Coase, R. H. "The Problem of Social Cost." The Journal of Law Economics 3 (October 1960):1-44.
- Davis, O. A., and Winston, A. B. "Some Notes on Equating Private and Social Cost." The Southern Economic Journal 32, No. 2 (October 1965): 113-26.

- Edison Electric Institute. Fuels for the Electric Utility Industry, 1971-1985. New York, 1972.
- "The Effluent Fee Approach for Controlling Air Pollution." Duke Law Journal, October 1970, pp. 943-90.
- Environmental Protection Agency. "EPA Energy Quality Model Documentation." Unpublished. Research Triangle Park, N.C., October 3, 1972.
- Ethridge, D. W. An Economic Study of the Effect of Municipal Sewer Surcharges on Industrial Wastes. Report 41, Water Resources Research Institute, North Carolina State University, Raleigh, N.C., November 1970.
- Farmer, M. H., and Bertrand, R. R. Long Range Sulfur Supply and Demand Model. Prepared by Esso Research and Engineering Company, Government Research Laboratory, Linden, N.J., for Environmental Protection Agency, Division of Control Systems, Office of Air Programs, November 1971.
- Federal Power Commission. Statistics of Privately Owned Electric Utilities in the United States - 1968, 1969, 1970 - Class A and B Companies, 1970. Washington, D.C., 704 pp.
- Fogel, M. E., Johnston, D. R.; Collins, R. L.; LeSourd, D. A.; Gerstle, R. W.; and Hill, E. L. Comprehensive Economic Cost Study of Air Pollution Control Costs for Selected Industries and Selected Regions. Final Report prepared by the Research Triangle Institute, Research Triangle Park, N.C., on Contract NO. CPA 22-69-79 for National Air Pollution Control Administration, 1970.
- Frank, Ernest H. Sulfur Review and Outlook. First Manhattan Co., New York, May 24, 1968.
- Freeman, A. M., III. The Economics of Pollution Control and Environmental Quality. New York: General Learning Press, 1971, pp. 1-27.
- Graham, Robert E., Jr.; Degraff, Henry L.; and Trott, Edward A., Jr. "State Projections of Income, Employment, and Population." Survey of Current Business 52, No. 4 (April 1972):22-48.
- Hausgaard, Olaf. "Proposed Tax on Sulfur Content of Fossil Fuels." Public Utilities Fortnightly, September 16, 1971, pp. 27-33.
- Heller, Walter W. "Economic Growth and Ecology: An Economist's View." Monthly Labor Review, November 1971, pp. 14-21.
- Hittman Associates, Inc. Cost Nomographs of Selected Sulfur Dioxide Abatement Methods. Contract No. EHSD-71-43 for Environmental Protection Agency, Office of Air Programs, Columbia, Md., 1972.
- Hittman Associates, Inc. Electrical Power Supply and Demand Forecasts for the United States through 2050. Prepared for Environmental Protection Agency (EPA), Columbia, Md., 1972.

- Hittman Associates, Inc. Study of the Future Supply of Natural Gas for Electrical Utilities. Prepared for Environmental Protection Agency, Office of Air Programs, Columbia, Md., February 1972.
- Hoskins, W. Lee. "Let the Pricing System Provide the Incentive." Industrial Water Engineering, April 1971, pp. 8-10.
- Hottel, H. C., and Howard, J. B. "Nuclear Power." In New Energy Technology: Some Facts and Assessments. Cambridge, Mass.: M.I.T. Press, 1972.
- Kapp, K. W. "Environmental Disruption and Social Costs: A Challenge to Economics." Kyklos 23 (1970):833-48.
- M. W. Kellogg Company. Detailed Cost Breakdown for Selected Sulfur Oxide Control Processes. Prepared for Environmental Protection Agency, Office of Air Programs, Division of Control Systems, Washington, D.C., 1971, 21 pp.
- M. W. Kellogg Company. Evaluation of SO₂ Control Processes. Prepared for Environmental Protection Agency, Office of Air Programs, Division of Control Systems, Washington, D.C., 1971, 264 pp.
- Kneese, A. V. (presiding). "Taxation and Management of Environmental Quality." First Concurrent Conference Session, National Tax Association. Columbus, Ohio, September 1971, pp. 88-147.
- Kohn, Robert E. "Linear Programming Model for Air Pollution Control: A Pilot Study of the St. Louis Airshed." Journal of the Air Pollution Control Association 20 (February 1970):325-60.
- LeSourd, D. A., and Bunyard, F. L., eds. Comprehensive Study of Specified Air Pollution Sources to Assess the Economic Impact of Air Quality Standards. Research Triangle Institute, Research Triangle Park, N.C., and Environmental Protection Agency. Final Report on Contract No. 68-02-0088 for Environmental Protection Agency, Division of Effects Research, Research Triangle Park, N.C., 1972.
- LeSourd, D. A.; Vogel, M. E.; Schleicher, A. R.; Bingham, T. H.; Gerstle, R. W.; Hill, E. L.; and Ayer, F. A. Comprehensive Study of Specified Air Pollution Sources to Assess the Economic Effects of Air Quality Standards. Research Triangle Institute, Research Triangle Park, N.C. Final Report on Contract No. CPA 70-60 for Environmental Protection Agency, Division of Economic Effects Research, Washington, D.C., 1970.
- Mac Avoy, Paul W. "The Regulation-induced Shortage of Natural Gas." Journal of Law and Economics 14, No. 1 (April 1971):167-199.
- Makin, John H. "Pollution as a Domestic Distortion in Welfare Theory." Land Economics, May 1971, pp. 185-88.

- Meade, J. E. "External Economics and Diseconomies in a Competitive Situation." The Economic Journal, March 1952, pp. 54-67.
- Mishan, E. J. "The Postwar Literature on Externalities: An Interpretative Essay." Journal of Economic Literature 9 (March 1971):1-28.
- Mishan, E. J. "A Survey of Welfare Economics, 1939-59." The Economic Journal 70 (June 1960):197-256.
- Mishan, E. J. "Welfare Criteria for External Effects." The American Economic Review, September 1961, pp. 594-613.
- Morrison, Warren E., and Readling, Charles L. An Energy Model for the United States, Featuring Energy Balances for the Years 1947 to 1965 and Projections and Forecasts to the Years 1980 and 2000. U.S. Department of the Interior, Bureau of Mines, Washington, D.C., 1968.
- National Academy of Science and National Academy of Engineering. Abatement of Sulfur Oxide Emissions from Stationary Combustion Sources. Ad Hoc Panel on Control of Sulfur Dioxide from Stationary Combustion Sources, Committee on Air Quality Management, Committees on Pollution Abatement and Control, Division of Engineering, National Research Council, Washington, D.C., 1970.
- National Academy of Sciences and National Academy of Engineering. Man, Materials, and Environment. Prepared for the National Commission on Materials Policy, Washington, D.C., 1973.
- National Air Pollution Control Administration. Air Quality Criteria for Sulfur Oxides. Publ. No. AP-50. Washington, D.C.: U.S. Government Printing Office, 1969.
- National Coal Association, Division of Economics and Statistics. Steam-Electric Plant Factors, 1969. Washington, D.C., 1969, 118 pp.
- National Economic Research Associates, Inc. Fuels for the Electric Utility Industry 1971-1985. Prepared for the Edison Electric Institute, New York, August 1972.
- National Economic Research Associates, Inc. Possible Impact of Costs of Costs of Selected Pollution Control Equipment on the Electric Utility Industry and Certain Power Intensive Consumer Industries. Prepared for Council on Environmental Quality, Washington, D.C., January 5, 1972.
- National Petroleum Council, Committee on U.S. Energy Outlook. U.S. Energy Outlook: An Initial Appraisal, 1971-1985, (vols. 1 and 2). Washington D.C., November 1972.
- Plott, C. R. "Externalities and Corrective Taxes." Economica, February 1966, pp. 84-87.
- Private communication with Gary Rochelle, Environmental Protection Agency, Research Triangle Park, N.C.

- Robson, F. L., et al. Technological and Economic Feasibility of Advanced Power Cycles and Methods of Producing Nonpolluting Fuels for Utility Power Stations. Final report on Contract No. CPA 22-69-114 for the Environmental Protection Agency by VARL, 1970.
- Rochelle, G. T. "A Critical Evaluation of Processes for the Removal of SO₂ from Power Plant Gas." Presented at Air Pollution Control Association Meeting. Chicago, Ill., 1973.
- Ruff, Larry E. "The Economic Common Sense of Pollution." The Public Interest 10 (Spring 1970):69-85.
- Slack, A. V., and Harrington, R.E. "Removal of Sulfur Dioxide from Power Plant Stack Gas: Status of Limestone Processes. Presented at Second International Clean Air Congress of the International Union of Air Pollution Prevention Association, Dec. 6-11, 1970, Washington, D.C.
- Solow, Robert M. "The Economist's Approach to Pollution and Its Control." Science 173 (August 6, 1971):498-503.
- "Symposium: The future of the U.S. wage-price policy: Weidenbaum, Murray L., New initiatives in national wage and price policy; Ackley, Gardner, An incomes policy for the 1970's; Madden, Carl H., Controls or competition--what's at issue? Houthakker, Hendrick S., Are controls the answer?" The Review of Economics and Statistics 54, No. 3 (August 1972):213-17.
- Teller, A. "Air-pollution Abatement: Economic Rationality and Reality." Daedalus, Fall 1967, pp. 1083-98.
- Tennessee Valley Authority. Sulfur Oxide Removal from Power Plant Stack Gas: Use of Limestone in Wet-scrubbing Processes. Prepared for U.S. Department of Health, Education, and Welfare, National Air Pollution Control Administration, Washington, D.C., 104 pp.
- Turvey, Ralph. "On Divergences between Social Cost and Private Cost." Economica, August 1963, pp. 309-13.
- Tybout, R. A. "Pricing of Pollution." The Bell Journal of Economics and Management Science 3, No. 1 (Spring 1972):252-66.
- U.S. Congress. House of Representatives. Energy "Demand" Studies: An Analysis and Appraisal. Prepared for the Committee on Interior and Insular Affairs, Washington, D.C., September 1972.
- U.S. Department of Health, Education, and Welfare. Control Techniques for Sulfur Oxide Air Pollutants, Washington, D.C., January 1969.
- U.S. Department of Health, Education, and Welfare, A Summary of Electric Power Plant Fuel Use, Sulfur Emissions, and Fuel Cost (1969 Data), Environmental Protection Agency, Office of Air Programs, Fuel Policy Section, Washington, D.C., 1971.

U.S. Department of the Interior, Bureau of Mines. Transportation Costs of Fossil Fuels (interim report). Washington, D.C., 1971.

U.S. Environmental Protection Agency, Office of Air Quality and Standards. Control Techniques for Sulfur Oxide Air Pollutants. (2nd ed. draft), Washington, D.C., 1972.

Wellisz, Stanislaw. "On External Diseconomies and the Government-assisted Invisible Hand." Economica, November 1964, pp. 345-62.

Winger, John G.; Emerson, John D.; and Gunning, Gerald D. Outlook for energy in the United States. The Chase Manhattan Bank, N.A., New York, 1968.

Winton, John M. "Dark Cloud on Sulfur's Horizon." Chemical Week 108, No. 6 (February 10, 1971):25-36.